NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER

Bethesda, Maryland 20034

DATA GENERATOR FOR THE IDEALIZATION FOR FINITE ELEMENT STRUCTURAL ANALYSIS OF NAVAL SHIP FLAT PLATED GRILLAGES WITH MULTIPLE OPENINGS

by

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DATA GENERATOR FOR THE IDEALIZATION FOR FINITE ELEMENT STRUCTURAL ANALYSIS OF NAVAL SHIP FLAT PLATED GRILLAGES WITH MULTIPLE OPENINGS

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Naval Ship Research and Development Center
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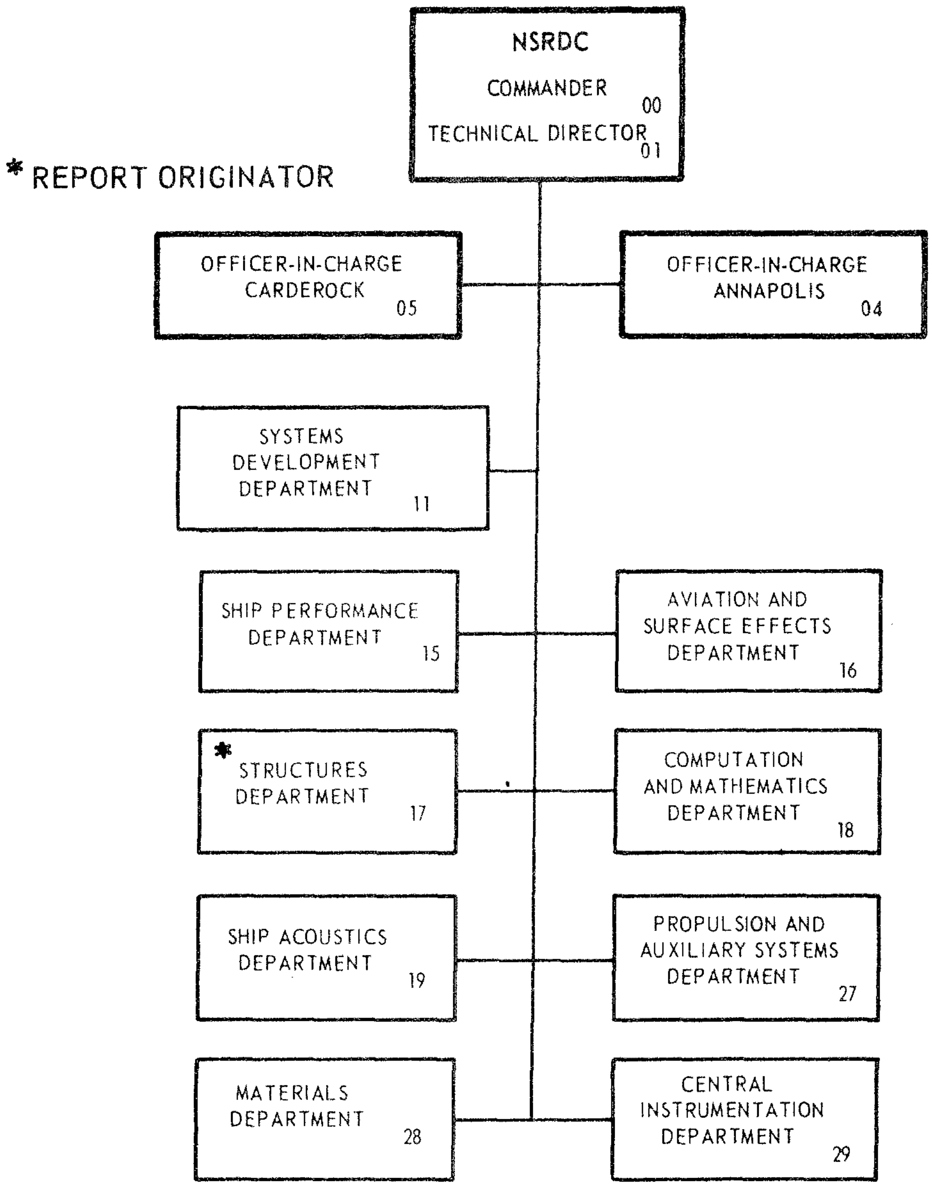

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ABSTRACT

A computer program has been developed for the automatic elementizing of flat-plated ship structural grillages with up to five openings and uniform pressure loads normal to the planar surface. Its purpose is to shorten the preliminary work of preparing data for analysis by the finite element method. The input to the program consists of punched cards which define the plate geometry, and the output consists of a tape which is directly read by the general-purpose finite element program NASTRAN to produce a plot of the user's elementized structure.

Modifications to this program will shortly be undertaken to allow the program to accept in-plane loads and hull geometry.

ADMINISTRATIVE INFORMATION

The program DATGEN was completed during the time period December 1970-October 1971 under NAVSHIPS project SF 350342422, Task Area 311, Task 15077, by Paul M. Meyer of Code 1735.

INTRODUCTION

BACKGROUND

In this age of automation, computer programs have taken over many of the functions formerly handled by engineers. This is especially evident in the field of structural analysis. However, the complex procedures and analyses required to evaluate designs for new structures together with the increasing use of the finite element method of analysis have created the need for a massive amount of extremely time-consuming preliminary work.

For example, before an engineer can utilize a very sophisticated finite element program such as the NASA general purpose structural computer program NASTRAN,[1] he must break down his real structure into a very

[1] C.W. McCormick, "The NASTRAN User's Manual," NASA Report SP-222 (Oct 1969).

large number of small geometric elements. The number of cards necessary for even the shortest NASTRAN run on a fairly simple structure is in the order of 500 cards, and some very complex structures require as many as 3000.

It is understandable that these preliminary assemblies can take as long as 3 months for a structure of moderate size when one considers the potential for errors in the manual generation of data plus the errors which are extremely probable during the keypunching of so many cards. Automated generation of data seems to be a reasonable answer to this time-consuming and costly process.

Many naval ship structures lend themselves to automated data generation solutions. The value of automated data generation will continue to increase with the increasing need for solutions to larger and more complex structures in a reasonable amount of time; it is accurate and gives the engineer much more time to spend on problems which truly require his engineering judgment.

STATEMENT OF THE PROBLEM

Need for the Program

Although a ship is made up of many complex structural pieces, the flat-plated structural assembly seems to be common to all ships. An automatic data generator which could elementize this type of structural component would certainly provide a good start toward the goal of elementizing a complete ship structure. Such a computer program would serve a dual purpose: (1) it would be of sufficient value to warrant its development as the first module within a collection of modules to elementize more complex structures and (2) it could serve as a guide to the complexities of the overall problem of general automated data generation.

The program described herein has been designated DATGEN.

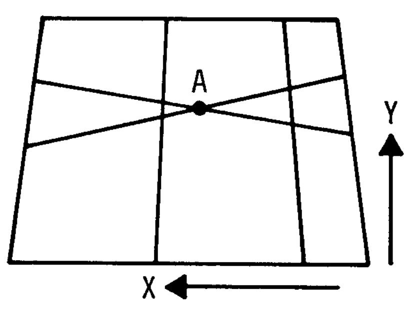
Criteria for Acceptable Input

The following is a list of the types of deck structure that are acceptable to computer program DATGEN and the restrictions that must be imposed.

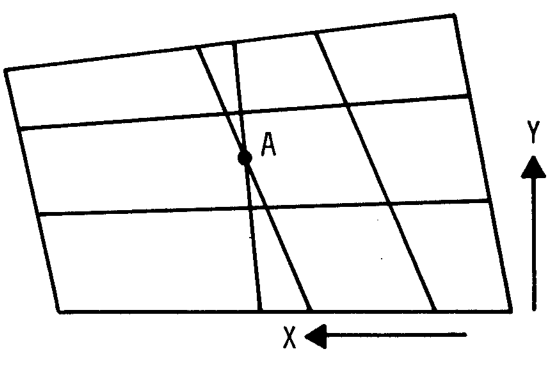
1. The deck assembly must be a quadrilateral.
2. The deck assembly can have stiffeners running in both the transverse and longitudinal directions. However, transverse stiffeners cannot intersect each other, and longitudinal stiffeners cannot intersect each other.

   See the illustration given below for further clarification.
3. Stiffeners can be terminated anywhere within the deck assembly. However, a terminated transverse stiffener whose straight-line extension would otherwise have intersected another transverse stiffener within the plate is not acceptable. The same restriction applies to longitudinal stiffeners.
4. The deck assembly can have up to five openings.
5. Any edge of the deck assembly can be completely constrained or constrained only in the MZ direction.
6. Uniform loads can be placed normal to the plate.
7. The edge of a deck assembly can be bounded by a stiffener. If it is so bounded, then the stiffener must be continuous (i.e., it cannot be chopped).

Additional restrictions are explained in the section on restrictions along with ways of bypassing some of them.



This deck plate cannot be handled by DATGEN because Point A is common to two longitudinal stiffeners.



This deck plate cannot be handled by DATGEN because Point A is common to two transverse stiffeners.

GENERAL DESCRIPTION OF DATGEN SUBROUTINES

Figure 1 represents the flow of computer logic through the different subroutines. The subroutines and their associated functions are as follows:

1. GENER - Executive routine under whose control all of the steps in elementizing a flat-plated structural assembly are carried out. The first function of the routine is to read in all of the user's input information. GENER then calls the appropriate subroutines to solve the problem and print out the elementized structure.
2. OTPT - Subroutine which prints out the user's input information. This program is called by GENER to write out the user's information in an easily understood form, to check for errors in keypunching, and to keep records when the user wants to vary specific inputs while keeping the other items fixed (e.g., parametric studies).
3. LINES - Slave subroutine which given two sets of points, each of which determines a line, finds the intersection of the two specified lines.
4. SPEC - Subexecutive routine which is called by GENER to elementize certain types of patches. A patch is defined as a quadrilateral determined by the intersection of four lines; these lines are either beams or the edges of the entire plate. Each patch is elementized separately making sure that nodes are consistent along common boundaries. There are basically two types of patches as depicted in Figure 2. One type (indicated by the symbol *) is handled by SPEC and the other (indicated by the symbol +) by GENER itself. The patches elementized by SPEC are those which have one side in common with the edge of the rectangle which bounds an opening.
5. TAKE - Slave subroutine used for the storage of nodes common to the boundaries of adjacent patches.
6. TEE - Slave subroutine used to store and extract information pertaining to the physical properties of the stiffeners.
7. FILL - Slave subroutine used for the storage of nodes common to the boundaries of adjacent patches.
8. CHOP - Subroutine which sets two variables if a stiffener is chopped within a patch.

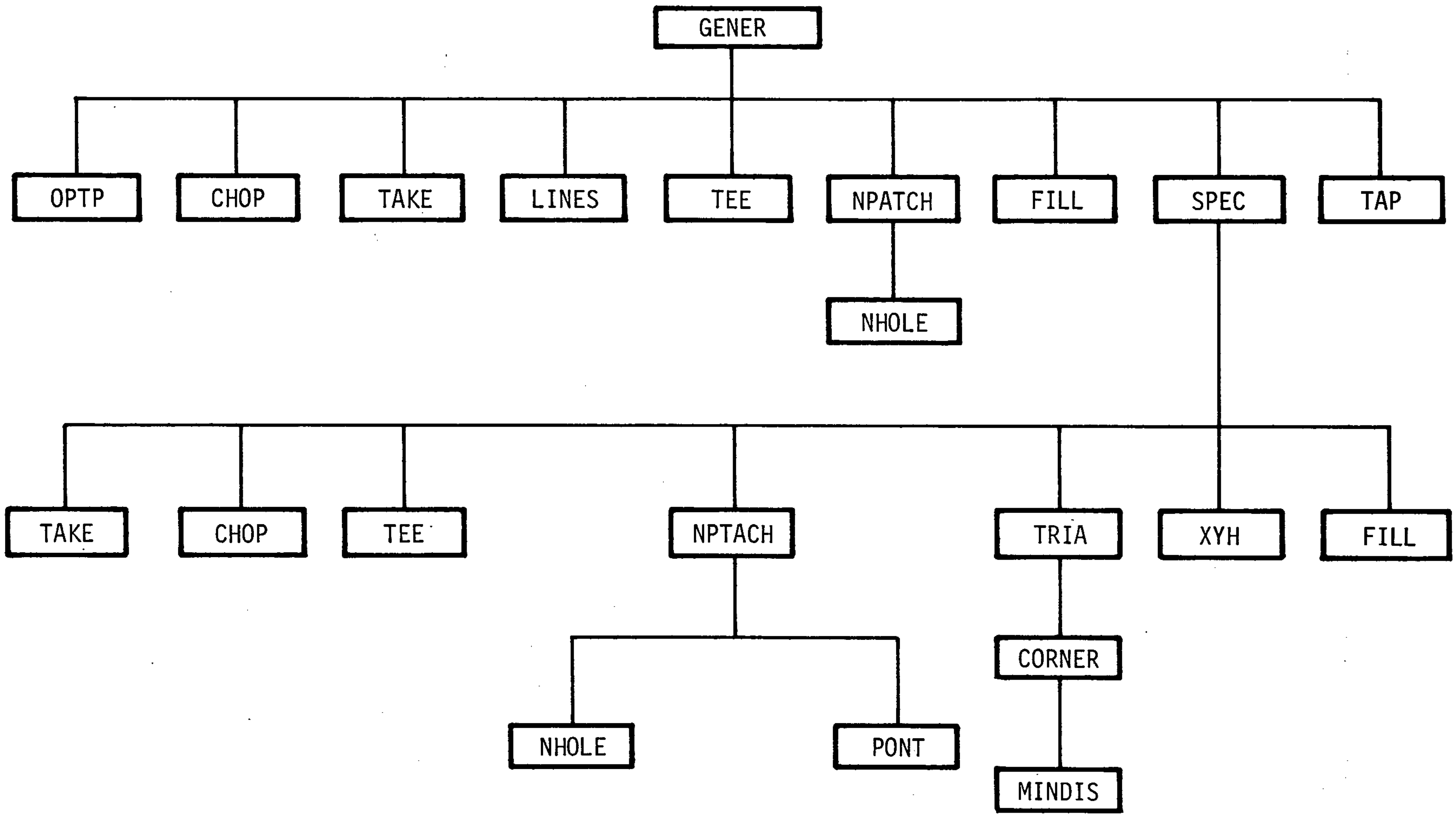


Figure 1 - Subroutine Flow Chart

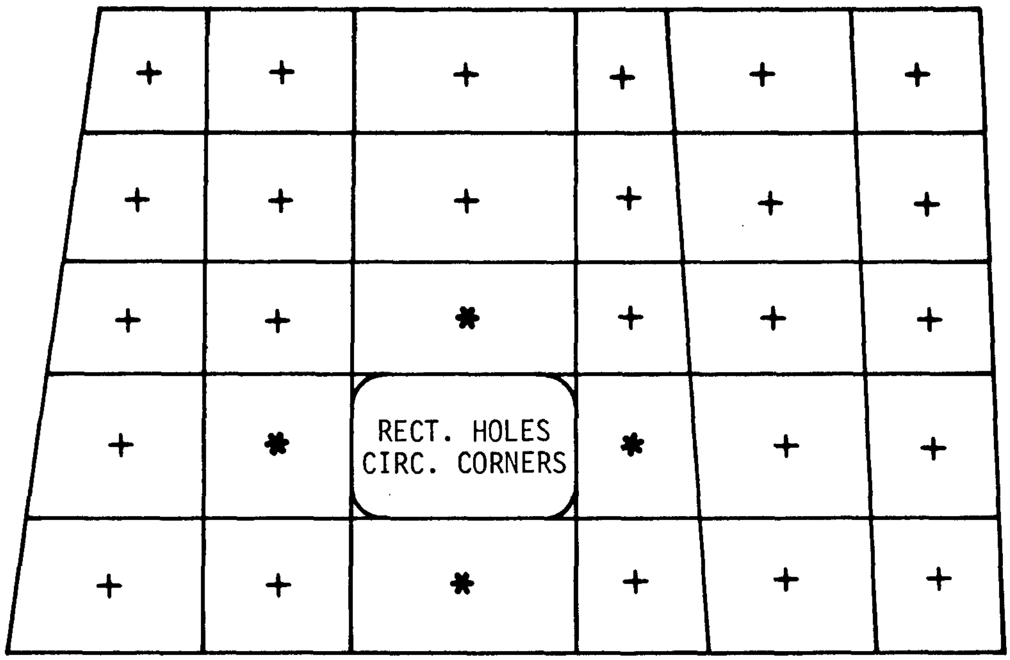


Figure 2 - Patch Types

9. NPATCH - Subroutine which, under the control of SPEC and GENER, actually elementizes each individual patch.

10. NHOLE - Subroutine called by NPATCH to assign unique grid point numbers to all the nodes of the finite elements.

11. PONT - Subroutine called by NPATCH to find the x- and y-coordinates along the sides of patches which are to be elementized by SPEC.

12. TRIA - Subroutine which elementizes the portion of the structure which is adjacent to the curved portion of an opening (i.e., the portions denoted by * in Figure 3).

13. CORNER - Subroutines which assign unique grid numbers to the nodes of the portion of the structure elementized by TRIA.

14. MINDIS - Slave minimum distance subroutine.

15. XYH - Slave subroutine which, given the coordinates of three corners of a square, finds the coordinates of the fourth corner.

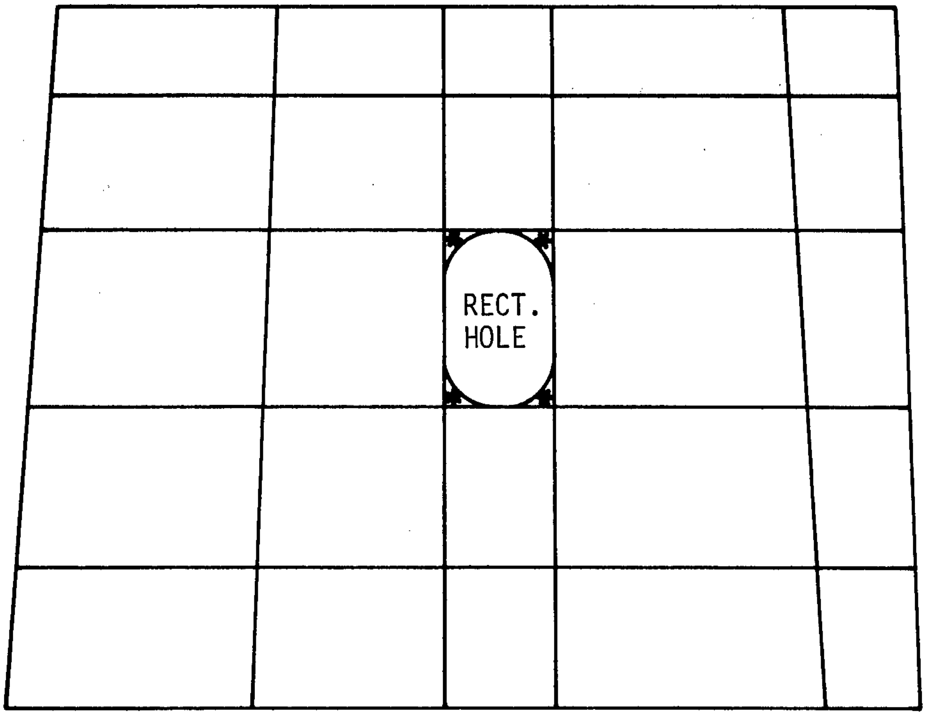


Figure 3 - Curved Patch

16. TAP - Subroutine which stores all of the output information on catalogued files. This method of output storage allows the user to add or delete to the output file at a later date.

COMPUTER INFORMATION

COMPUTER SYSTEM REQUIREMENTS

The program is written in the FORTRAN IV language for processing under the Scope Operating System on a CDC 6700 Computer.

With minor changes and modifications to the control cards, the program can be run on almost any third-generation computer provided that the system has the option to plot a tape for the SC-4020. If this option is unavailable, other changes can be made so that the output from the program is in the form of punched cards which serve as input to NASTRAN. NASTRAN, which needs the SC-4020 routines to generate a plotting tape, can then be run on a different computer.

SC-4020 INFORMATION

The current version of the program DATGEN directly accesses NASTRAN. In order to run the current version with no modifications, NASTRAN must be available on the computer system. With minor modifications, this stipulation can be removed.

In addition to the regular input (as will be explained later), the program requires inclusion of the executive control cards and the case control cards which NASTRAN processes to produce on SC-4020 plot. The first card after the set of regular input data cards is a fixed point number punched in the I5 format which specifies how many NASTRAN control cards. follow it. A test example is given later in the report.

CONTROL CARDS

The control cards are tabulated below along with a brief description.

Control Card	Explanation
CAPDSGC, CM2000000, T700, MT2, P3.	Job card - this card is specific to the CDC 6700 computer facility where the program is run.
CHARGE, CAPD, 173008601, CC, B.	Change card - this card is specific to the CDC 6700 computer facility when the program is run.
ATTACH (FIND1, CAPDFIND1, SD-23)	Attach permanent file card - the current version of the program DATGEN is stored in a permanent file and can be accessed by the use of this card.
RFL, 100.	Change field length card - this reduces the field length to 100 which is the suggested field length for mounting a tape.
REQUEST, TAPE 7, HI. (CA0930/RING)	Mount tape card - the card requests a tape which will contain the output from the program DATGEN. This tape will then serve as the input to NASTRAN.
RFL, 150000.	Change field length card - this card changes the field length to 150000 which is the required size for the running of DATGEN.
FIND1.	Execution card - this card causes the program DATGEN to be executed.
UNLOAD (TAPE 7, FIND1)	Unload card - this card causes the unloading of the permanent file FIND1 and the tape TAPE 7 after they are no longer needed.
RFL, 200000.	Change field length card - this card changes the field length to 200000 which is the suggested size for the running of NASTRAN.
LABEL(NASTRAN, L = CAMKNASTRAN111, R, D = HY) (CA0548/NORING)	Request labeled tape card - this card requests the labeled tape which contains NASTRAN.
MAP(OFF)	Control of map printing card - this card is required by NASTRAN.

RFL.100.	Change field length card - this card reduces the field length to 100 which is the suggested field length for mounting a tape.
REQUEST PLT2, HI, S. (CB0104 RING)	Mount tape card - this card requests a tape for the SC-4020 plots.
RFL, 200000.	Change field length card - this card changes the field length to 200000 which is the suggested size for the running of NASTRAN.
SKIPB(INPUT, 2, 17, B) SKIPF(INPUT, 1, 17, B)	Skip file cards - these cards are used to position the NASTRAN INPUT tape.
NOREDUCE.	Noreduce card - this card causes the field length to remain at a constant 200000.
NASTRAN.	Execution card - this card causes the program NASTRAN to be executed.

COMMENTS

The user is referred to the NASTRAN User's manual[1] for questions pertaining to the executive control cards and the case control cards required by NASTRAN.

The SCOPE Reference Manual[1] should be consulted for questions pertaining to the CDC 6700 control cards.

DATGEN users who have any special problems should contact the originator (NSRDC Code 1730) rather than attempt to make changes to the program.

INPUT REQUIREMENTS

DATA PREPARATION

Careful preparation of the input data is vitally important; otherwise the results will not be valid.

Several types of input forms are required for the solution of a problem. A careful review of the following descriptions and formats of the

[1] Control Data Corporation, "6000 Series Computer Systems Scope 93 Reference Manual," CDC Publication 60305200. (1970).

required input data will provide the guidance needed for the preparation of program data. For additional clarification, a test example is given later in the report together with a further explanation of restrictions.

General Information Card						
Number of Different Materials	Number of Openings	Number of Different Plate Properties	Number of Different Stiffener Properties	Number of Longitudinal Bays	Number of Transverse Bays	
1 2 3 4 5	6 7 8 9 10	11 12 13 14 15	16 17 18 19 20	21 22 23 24 25	26 27 28 29 30	31 32 33 34 35 36 37 38 39 40
1						

Columns	Coding Symbol	Format	Additional Description
1- 5	MAT	I5	This value is either 1 or 2. If the stiffeners and the plates are made of the same material, the value is 1. If the plate material (all plates must be made of the same material) and the stiffener material (all stiffeners must be made of the same material) are different, then the value is 2.
6-10	NU	I5	The number of openings in the plate.
11-15	NPROP	I5	The number of different plate thicknesses within the deck plate. Note that the thickness of the deck plating can vary only between transverse stiffeners.
16-20	KVAL	I5	The number of different stiffeners within the deck plate.
21-25	NLL	I5	The number of longitudinal bays (i.e., the number of longitudinal stiffeners -1).
26-30	NIT	I5	The number of transverse bays (i.e., the number of transverse stiffeners -1).

Notes:

1. The maximum number of openings in a plate is 5 (i.e., NU$\leq$5).
2. The maximum number of different plate property cards is 25 (i.e., NPROP$\leq$25).
3. The maximum number of different stiffener property cards is 52 (i.e., KVAL$\leq$52).
4. The maximum number of longitudinal bays and transverse bays is 25 (i.e., NLL$\leq$25 and NTT$\leq$25).

<table>
<tr><td colspan="60">Edge Condition Card</td></tr>
<tr><td colspan="20">Edge Beams</td><td colspan="40">Edge Constraints</td></tr>
<tr><td colspan="5">Edge 1</td><td colspan="5">Edge 2</td><td colspan="5">Edge 3</td><td colspan="5">Edge 4</td><td colspan="10">Edge 1</td><td colspan="10">Edge 2</td><td colspan="10">Edge 3</td><td colspan="10">Edge 4</td></tr>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td><td>14</td><td>15</td><td>16</td><td>17</td><td>18</td><td>19</td><td>20</td><td>21</td><td>22</td><td>23</td><td>24</td><td>25</td><td>26</td><td>27</td><td>28</td><td>29</td><td>30</td><td>31</td><td>32</td><td>33</td><td>34</td><td>35</td><td>36</td><td>37</td><td>38</td><td>39</td><td>40</td><td>41</td><td>42</td><td>43</td><td>44</td><td>45</td><td>46</td><td>47</td><td>48</td><td>49</td><td>50</td><td>51</td><td>52</td><td>53</td><td>54</td><td>55</td><td>56</td><td>57</td><td>58</td><td>59</td><td>60</td></tr>
</table>

1

Columns	Coding Symbol	Format	Additional Descriptions
1- 5	NEB(2)	I5	Set value to 1 if there is a stiffener on the first edge. Otherwise leave blank.
6-10	NEB(2)	I5	Set value to 1 if there is a stiffener on the second edge. Otherwise leave blank.
11-15	NEB(3)	I5	Set value to 1 if there is a stiffener on the third edge. Otherwise leave blank.
16-20	NEB(4)	I5	Set value to 1 if there is a stiffener on the fourth edge. Otherwise leave blank.
21-30	KSPC(1)	I10	To fix the first edge, set value to 12345. Otherwise leave blank.
31-40	KSPC(2)	I10	To fix the second edge, set value to 12345. Otherwise leave blank.
41-50	KSPC(3)	I10	To fix the third edge, set value to 12345. Otherwise leave blank.
51-60	KSPC(4)	I10	To fix the fourth edge, set value to 12345. Otherwise leave blank.

Plate Property Cards									
First Thickness (inches)	Second Thickness (inches)	Third Thickness (inches)							I^{th} Thickness (inches)
1 2 3 4 5 6 7 8	9 10 11 12 13 14 15 16	17 18 19 20 21 22 23 24	25 26 27 28 29 30 31 32	33 34 35 36 37 38 39 40	41 42 43 44 45 46 47 48	49 50 51 52 53 54 55 56	57 58 59 60 61 62 63 64	65 66 67 68 69 70 71 72	73 74 75 76 77 78 79 80

Columns	Coding Symbol	Format	Additional Description
I-8	THIC(I)	F8.3	The thickness to be written on the I^{th} thickness property card for deck plating.

Bay Plate Thickness Card

First Transverse Bay Thickness Index	Second Transverse Bay Thickness Index	Third Transverse Bay Thickness Index	…	I^{th} Transverse Bay Thickness Index	
1 2 3	4 5 6	7 8 9	10 … 72	73 74 75	76 77 78 79 80

Columns	Coding Symbol	Format	Additional Description
1-3	NQ(I)	I3	If the value of NQ(I)=J, then the I^{th} transverse bay has a thickness of THIC(J).

Stiffener Property Cards				
Stiffener Catalog Number	Web Depth (inches)	Web Thickness (inches)	Flange Breadth (inches)	Flange Thickness (inches)
1 2 3 4 5	6 7 8 9 10 11 12 13	14 15 16 17 18 19 20 21	22 23 24 25 26 27 28 29	30 31 32 33 34 35 36 37

1

Columns	Coding Symbol	Format	Additional Description
1- 5	KV(I)	I5	The number from the Structural Shape Catalog to define the properties on the I^{th} stiffener property card. If the I^{th} stiffener card references a built-up member, set KV(I) to 0.
6-13 14-21 22-29 29-37	BM(I,1) BM(I,2) BM(I,3) BM(I,4)	F8.3 F8.3 F8.3 F8.3	The value of the four stiffener characteristics for the I^{th} stiffener property card. If KV(I) is between 1 and 173 (i.e., if the stiffener is chosen from the Structural Shape Catalog), the (BM(I,J), J=1,4) should be left blank. If the stiffener is a built-up member and therefore KV(I)=0, then (BM(I,J), J=1,4) should be filled in the following manner: Column 1(J=1) - web depth Column 2(J=2) - web thickness Column 3(J=3) - flange breadth Column 4(J=4) - flange thickness

Longitudinal Stiffener Cards							
	Geometry						
Stiffener Index	X1 (inches)	Y1 (inches)	X2 (inches)	Y2 (inches)	Property Reference Number	Stiffener Continuity Number	Chopped Value (inches)
1–5	6–13	14–21	22–29	30–37	38–42	43–47	48–55

Columns	Coding Symbol	Format	Additional Description
1- 5	J	I5	This value specifies the order in which the stiffeners in the longitudinal direction occur.
6-13	XYL(J,1,1)	F8.3	The X value of the initial point of the J^{th} longitudinal stiffener.
14-21	XYL(J,1,2)	F8.3	The Y value of the initial point of the J^{th} longitudinal stiffener.
22-29	XYL(J,2,1)	F8.3	The X value of the terminal point of the J^{th} longitudinal stiffener.
30-37	XYL(J,2,2)	F8.3	The Y value of the terminal point of the J^{th} longitudinal stiffener.
38-42	KEL(J)	I5	If KEL(J)=N, then the J^{th} longitudinal stiffener has the properties as specified by KV(N) or (BM(N,J), J=1,4). (Depending on whether the stiffener is a built-up member or a stiffener from the Structural Shape Catalog).
43-47	NCL(J,1)	I5	This value can be 0, 1, or 2. It is to be assigned in the following manner: 0 - J^{th} stiffener is continuous throughout entire plate (i.e., it begins on Edge 1 and terminates on Edge 3). 1 - J^{th} stiffener begins on Edge 1 and is terminated before Edge 3. 2 - J^{th} stiffener begins on Edge 3 and is terminated before Edge 1.
48-55	CORDL(J)	F8.3	The X value at which the J^{th} stiffener is terminated. If stiffener is not terminated, leave this value blank.

Note: The maximum number of stiffeners in either the transverse or longitudinal direction is 26.

Transverse Stiffener Cards							
Stiffener Index	Geometry				Property Reference Number	Stiffener Continuity Number	Chopped Value (inches)
	X1 (inches)	Y1 (inches)	X2 (inches)	Y2 (inches)			
1 2 3 4 5	6 7 8 9 10 11 12 13	14 15 16 17 18 19 20 21	22 23 24 25 26 27 28 29	30 31 32 33 34 35 36 37	38 39 40 41 42	43 44 45 46 47	48 49 50 51 52 53 54 55
1							

Columns	Coding Symbol	Format	Additional Description
1- 5	J	I5	This value specifies the order in which the stiffeners in the longitudinal direction occur.
6-13	XYT(J,1,1)	F8.3	The X value of the initial point of the J^{th} transverse stiffener.
14-21	XYT(J,1,2)	F8.3	The Y value of the initial point of the J^{th} transverse stiffener.
22-29	XYT(J,2,1)	F8.3	The X value of the terminal point of the J^{th} transverse stiffener.
30-37	XYT(J,2,2)	F8.3	The Y value of the terminal point of the J^{th} transverse stiffener.
38-42	KET(J)	I5	If KET(J)=N, then the J^{th} transverse stiffener has the properties as specified by KV(N) or (BM(N,J), J=1,4). (Depending on whether the stiffener is a built-up member or a stiffener from the Structural Shape Catalog).
43-47	NCT(J,1)	I5	This value can be 0, 1, or 2. It is to be assigned in the following manner: 0 - J^{th} stiffener is continuous throughout entire plate (i.e., it begins on Edge 4 and terminates on Edge 2). 1 - J^{th} stiffener begins on Edge 4 and is terminated before Edge 2. 2 J^{th} stiffener begins on Edge 2 and is terminated before Edge 4.
48-55	CORDT(J)	F8.3	The Y value at which the J^{th} stiffener is terminated. If stiffener is not terminated, leave this value blank.

Longitudinal Grid Fineness Card

Columns 1–3	Columns 4–6	Columns 7–9	…	Columns 73–75
Number of Divisions for First Bay	Number of Divisions for Second Bay	Number of Divisions for Third Bay	…	Number of Divisions for I^{th} Bay

Columns	Coding Symbol	Format	Additional Description
1-3	NBAYL (J)	I3	The number of divisions in the J^{th} longitudinal bay.

Notes: 1. The maximum number of divisions per bay is 50 (i.e., NBAYL(J) $\leq$ 50).

2. The total number of divisions in either the transverse or longitudinal direction is 250 (i.e., $\sum_{I=1}^{NLL}$ NBAYL(I) $\leq$ 250 and $\sum_{I=1}^{NTT}$ NBAYT(I) $\leq$ 250).

Transverse Grid Fineness Card

Columns 1-3	Columns 4-6	Columns 7-9	...	Columns 73-75
Number of Divisions for First Bay	Number of Divisions for Second Bay	Number of Divisions for Third Bay	...	Number of Divisions for I^{th} Bay

Columns	Coding Symbol	Format	Additional Description
1-3	NBAYT(J)	I3	The number of divisions in the J^{th} transverse bay.

	Load Condition Card		
	Load Index	Uniform Pressure Load (psi)	
	1 2 3 4 5	6 7 8 9 10 11 12 13	14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40
1			

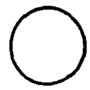
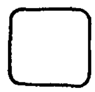
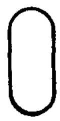
Columns	Coding Symbol	Format	Additional Description
1- 5	NLOAD	I5	The number of different patches which have a uniform pressure load on them. If NLOAD = 99, then the entire plate has a uniform pressure load. If NLOAD = 0, there is no pressure load on the plate.
6-13	XLD1	F8.3	If NLOAD = 99, then XLD1 is the uniform pressure load on the entire plate. If NLOAD ≠ 99, XLD1 should be left blank.

Note: The maximum number of individual patches that can be loaded is 50. Therefore, the valid values of NLOAD are 0, 99, 1-50.

Load Cards																																								
	Patch Row Number								Patch Column Number								Uniform Pressure Load (psi)																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
1																																								

Columns	Coding Symbol	Format	Additional Description
1- 8	NAD(1,I)	I8	If the value of NLOAD is between 1 and 50, NAD(1,I) is the row number of the I^{th} patch which has a uniform pressure load on it.
9-16	NAD(2,I)	I8	If the value of NLOAD is between 1 and 50, NAD(2,I) is the column number of the I^{th} patch which has a uniform pressure on it.
17-24	XLD(I)	F8.3	The uniform pressure load to be imparted on the patch defined by NAD(1,I) and NAD(2,I).

Plate Opening Cards										
Hole Type	Beam on Edge 1 (1-yes, 0-no)	Beam on Edge 2 (1-yes, 0-no)	Beam on Edge 3 (1-yes, 0-no)	Beam on Edge 4 (1-yes, 0-no)	Column Boundary Edge 1	Row Boundary Edge 2	Column Boundary Edge 3	Row Boundary Edge 4	Corner Divisions	Corner Radius (inches)
1 2 3 4 5	6 7 8 9 10	11 12 13 14 15	16 17 18 19 20	21 22 23 24 25	26 27 28 29 30	31 32 33 34 35	36 37 38 39 40	41 42 43 44 45	46 47 48 49 50	51 52 53 54 55 56 57 58
1										

Columns	Coding Symbol	Format	Additional Description
1- 5	NTY(I)	I5	The type number for the I^{th} opening. The four types of openings are defined as follows: Type 1  Type 2  Type 3  Type 4 
6-10	N1(I,1)	I5	The index of the column which bounds Edge 1 of the I^{th} opening.
11-15	N1(I,2)	I5	The index of the row which bounds Edge 2 of the I^{th} opening.
16-20	N1(I,3)		The index of the column which bounds Edge 3 of the I^{th} opening.
21-25	N2(I,4)		The index of the row which bounds Edge 4 of the I^{th} opening.
26-30	NEBE(I,1)	I5	Set equal to 1 if Edge 1 of the I^{th} opening is bounded by a stiffener. Otherwise set equal to 0.
31-35	NEBE(I,2)	I5	Set equal to 1 if Edge 2 of the I^{th} opening is bounded by a stiffener. Otherwise set equal to 0.
36-40	NEBE(I,3)	I5	Set equal to 1 if Edge 3 of the I^{th} opening is bounded by a stiffener. Otherwise set equal to 0.
41-45	NEBE(I,4)	I5	Set equal to 1 if Edge 4 of the I^{th} opening is bounded by a stiffener. Otherwise set equal to 0.

Columns	Coding Symbol	Format	Additional Description
46-50	NDIV(I)	I5	The number of divisions along the corner of the I^{th} opening. See Appendix A for a detailed explanation.
51-58	RADIUS(I)	F8.3	Radius of the corner of the I^{th} openings.

Note: $2 \leq NDIV(I) \leq 10$.

REQUIRED SEQUENCE OF INPUT CARDS

The required sequence of input cards is summarized below.

Sequence		Remarks
First Card	General Information Card	One card
Second Card	Edge Condition Card	One card
Third Card (Block)	Plate Property Cards	Number of cards depends on the number of different plate properties as indicated in Columns 11-15 of Input Card 1. Note: Ten different thicknesses are contained on each plate property card.
Fourth Card	Bay Thickness Card	One card
Fifth Card (Block)	Stiffener Property Cards	Number of cards depends on the number of different stiffener properties as indicated in Columns 16-20 of Input Card 1. Note: Number of cards = KVAL.
Sixth Card (Block)	Longitudinal Stiffener Cards	Number of cards depends on the number of longitudinal stiffeners. Note: Number of cards = NLL+1.
Seventh Card (Block)	Transverse Stiffener Cards	Number of cards depends on the number of transverse stiffeners. Note: number of cards = NTT+1.
Eighth Card	Longitudinal Grid Fineness Card	One card
Ninth Card	Transverse Grid Fineness Card	One card
Tenth Card	Load Condition Card	One card
Eleventh Card (Block)	Load Cards	Number of cards depends on number of different patches to be loaded. Note: If 50<LOAD<1, omit these cards. Otherwise number of cards = NLOAD.
Twelfth Card (Block)	Plate Opening Cards	Number of cards depends on number of openings in plate. Note: number of cards = NU. If NU = 0, omit these cards.

OUTPUT

There are two basic parts to the output of DATGEN. The first part consists of a detailed printout of all of the user input information. Every piece of information which the user specifies as input is printed out. The output for a typical deck plate is illustrated by a test example. The second part of the output is a list of all the output from the data generator as it is read by NASTRAN along with a sorted version of the NASTRAN input.

TEST EXAMPLE

INPUT CARDS

Before a user tries to set up a problem for DATGEN, he should make a sketch which contains all of the necessary information (i.e., all of the information to be punched on cards); see Figure 4. The input cards necessary to run a test problem illustrated by Figure 4 are indicated below to facilitate user understanding of the necessary input.

```
   1     2     2     2     5    10
   0     0     0     0           0     12345          0      12345
    1.0       2.0
 1   1   1   1   1   2   2   2   2   2
  5
 10
  1      0.0    300.0    550.0    300.0    10
  2      0.0    240.0    550.0    240.0     2
  3      0.0    180.0    550.0    180.0     2
  4      0.0    120.0    550.0    120.0     2
  5      0.0     60.0    550.0     60.0     2
  6      0.0      0.0    550.0      0.0     2
  1      0.0    300.0      0.0      0.0     1
  2     60.0    300.0     60.0      0.0     1     2      0.1
  3    120.0    300.0    120.0      0.0     1
  4    240.0    300.0    240.0      0.0     1
  5    360.0    300.0    360.0      0.0     1     2      0.1
  6    400.0    300.0    400.0      0.0     1
  7    430.0    300.0    430.0      0.0     1     2      0.1
  8    460.0    300.0    460.0      0.0     1
  9    490.0    300.0    490.0      0.0     1     2      0.1
 10    520.0    300.0    520.0      0.0     1     2      0.1
 11    550.0    300.0    550.0      0.0     1
 2  2   6   2   2
 2  2   5   5   2   2   4   4   2   2
 99        1.0
  3     2     4     5     2     1     1     0     1     3    30.0
  2     6     4     9     2     0     1     0     1     2    10.0
 35  NUMBER OF NASTRAN EXECUTIVE AND CASE CONTROL CARDS
```

```
ID MEYER CODE 853 NSRDC
SNASTRAN YES
TIME 5
APP DISP
SOL 1,0
ALTER 18
JUMP FINIS
ENDALTER
CEND
TITLE=TEST 1 DATA GENERATOR PLOT---ASR 21  02 LEVEL
ECHO=BOTH
PLOTID=ASR-21 02-LEVEL
OUTPUT(PLOT)
        SET 1 INCLUDE ELEMENTS 1 THRU 9999
        AXES MZ,MX,Y
VIEW 0.0,0.0,0.0
        CAMERA 3
        FIND SCALE ORIGIN 1 SET 1
        PLOT SET 1,ORIGIN 1,SHAPE
        SET 2 INCLUDE ELEMENTS 10001 THRU 14999
        AXES MZ,MX,Y
        VIEW 0.0,0.0,0.0
        FIND SCALE ORIGIN 1 SET 2
        PLOT SET 2,ORIGIN 1,SHAPE
        SET 3 INCLUDE ELEMENTS 15001 THRU 19999
        AXES MZ,MX,Y
        VIEW 0.0,0.0,0.0
        FIND SCALE ORIGIN 1 SET 3
        PLOT SET 3,ORIGIN 1,SHAPE
        SET 4 INCLUDE ALL

        AXES Z,MX,Y
        VIEW 45.0,45.0,0.0
        FIND SCALE ORIGIN 1 SET 4
        PLOT SET 4,ORIGIN 1,SHAPE
BEGIN BULK
```

NASTRAN CARDS WHICH CONTROL THE SC-4020 PLOTS

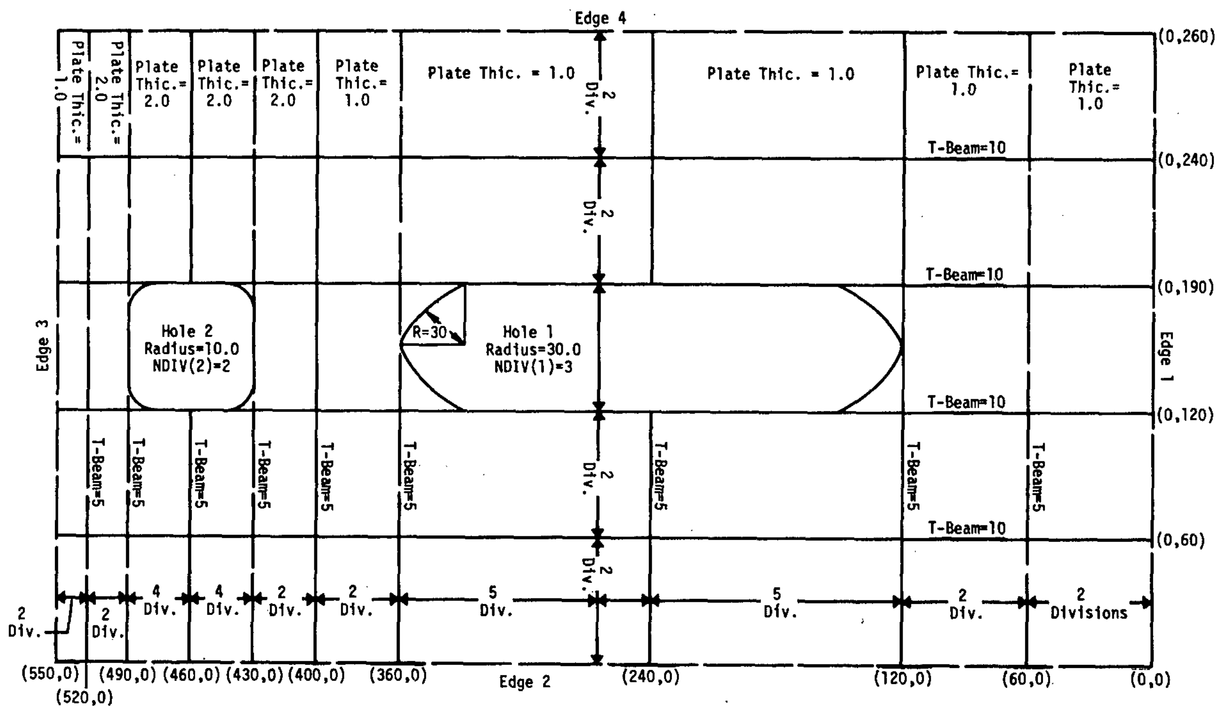


Figure 4 - Example of User Sketch of Necessary Information

TEST EXAMPLE OUTPUT

The following is a complete list of the user's input for the test example as printed out by DATGEN. Note that the order of the printed information approximates the order of the input data cards.

*** GENERAL INFORMATION ***

NUMBER OF DIFFERENT MATERIALS	=	1
NUMBER OF HOLES	=	2
NUMBER OF LONGITUDINAL BAYS	=	5
NUMBER OF TRANSVERSE BAYS	=	10
NUMBER OF DIFFERENT PLATE PROPERTIES	=	2
NUMBER OF DIFFERENT TEE PROPERTIES	=	2

*** EDGE CONDITIONS ***

EDGE NUMBER 1 IS FIXED IN THE MZ DIRECTION ONLY.

EDGE NUMBER 2 IS COMPLETELY FIXED.

EDGE NUMBER 3 IS FIXED IN THE MZ DIRECTION ONLY.

EDGE NUMBER 4 IS COMPLETELY FIXED.

EDGE NUMBER 1 IS NOT BOUNDED BY A TEE.

EDGE NUMBER 2 IS NOT BOUNDED BY A TEE.

EDGE NUMBER 3 IS NOT BOUNDED BY A TEE.

EDGE NUMBER 4 IS NOT BOUNDED BY A TEE.

*** PLATE THICKNESSES ***

TRANSVERSE BAY NO.	THICKNESS
1	1.000
2	1.000
3	1.000
4	1.000
5	1.000
6	2.000
7	2.000
8	2.000
9	2.000
10	2.000

*** STIFFENER PROPERTIES ***

LONGITUDINAL STIFFENERS

STIFFENER NO.	K-TEE VALUE	WEB DEPTH	WEB THICK.	FLANGE BREADTH	FLANGE THICK.
1	10	4.740	.180	3.950	.200
2	10	4.740	.180	3.950	.200
3	10	4.740	.180	3.950	.200
4	10	4.740	.180	3.950	.200
5	10	4.740	.180	3.950	.200
6	10	4.740	.180	3.950	.200

TRANSVERSE STIFFENERS

STIFFENER NO.	K-TEE VALUE	WEB DEPTH	WEB THICK.	FLANGE BREADTH	FLANGE THICK.
1	5	6.810	.130	2.080	.190
2	5	6.810	.130	2.080	.190
3	5	6.810	.130	2.080	.190
4	5	6.810	.130	2.080	.190
5	5	6.810	.130	2.080	.190
6	5	6.810	.130	2.080	.190
7	5	6.810	.130	2.080	.190
8	5	6.810	.130	2.080	.190
9	5	6.810	.130	2.080	.190
10	5	6.810	.130	2.080	.190
11	5	6.810	.130	2.080	.190

*** GEOMETRY ***

LONGITUDINAL STIFFENERS

STIFFENER NO.	X1	Y1	X2	Y2	CHOPPED	COORDINATE
1	0.000	300.000	550.000	300.000	0	-0.000
2	0.000	240.000	550.000	240.000	0	-0.000
3	0.000	180.000	550.000	180.000	0	-0.000
4	0.000	120.000	550.000	120.000	0	-0.000
5	0.000	60.000	550.000	60.000	0	-0.000
6	0.000	0.000	550.000	0.000	0	-0.000

TRANSVERSE STIFFENERS

STIFFENER NO.	X1	Y1	X2	Y2	CHOPPED	COORDINATE
1	0.000	300.000	0.000	0.000	0	-0.000
2	60.000	300.000	60.000	0.000	2	.100
3	120.000	300.000	120.000	0.000	0	-0.000
4	240.000	300.000	240.000	0.000	0	-0.000
5	360.000	300.000	360.000	0.000	2	.100
6	400.000	300.000	400.000	0.000	0	-0.000
7	430.000	300.000	430.000	0.000	2	.100
8	460.000	300.000	460.000	0.000	0	-0.000
9	490.000	300.000	490.000	0.000	2	.100
10	520.000	300.000	520.000	0.000	2	.100
11	550.000	300.000	550.000	0.000	0	-0.000

*** ELEMENTAL DIVISIONS ***

LONGITUDINAL BAYS

BAY NO.	NUMBER OF DIVISIONS
1	2
2	2
3	6
4	2
5	2

TRANSVERSE BAYS

BAY NO.	NUMBER OF DIVISIONS
1	2
2	2
3	5
4	5
5	2
6	2
7	4
8	4
9	2
10	2

*** LOADS ***

THERE IS A UNIFORM PRESSURE LOAD OF 1.000

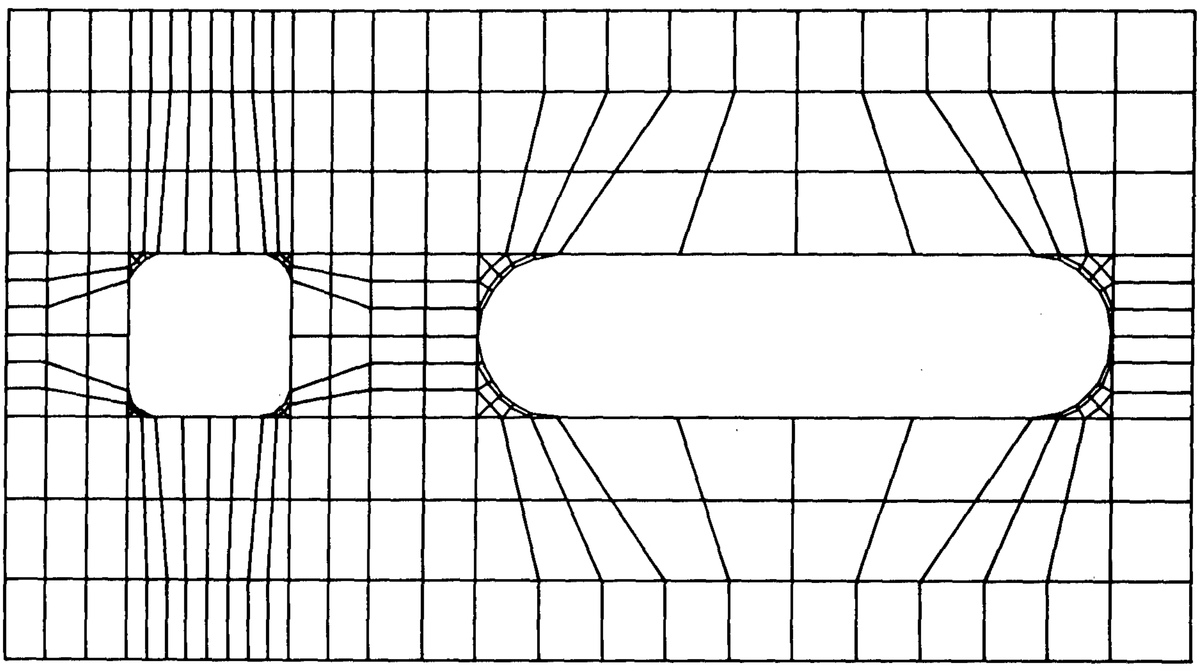
*** HOLES ***

HOLE NO.	HOLE TYPE	BOUNDARY 1	BOUNDARY 2	BOUNDARY 3	BOUNDARY 4
1	3	2	4	5	2
2	2	6	4	9	2

HOLE NO.	NUMBER OF DIVISIONS	RADIUS	STIFFENER 1	STIFFENER 2	STIFFENER 3	STIFFENER 4	COAM. TYPE
1	3	30.000	1	1	0	1	0
2	2	10.000	0	1	0	1	0

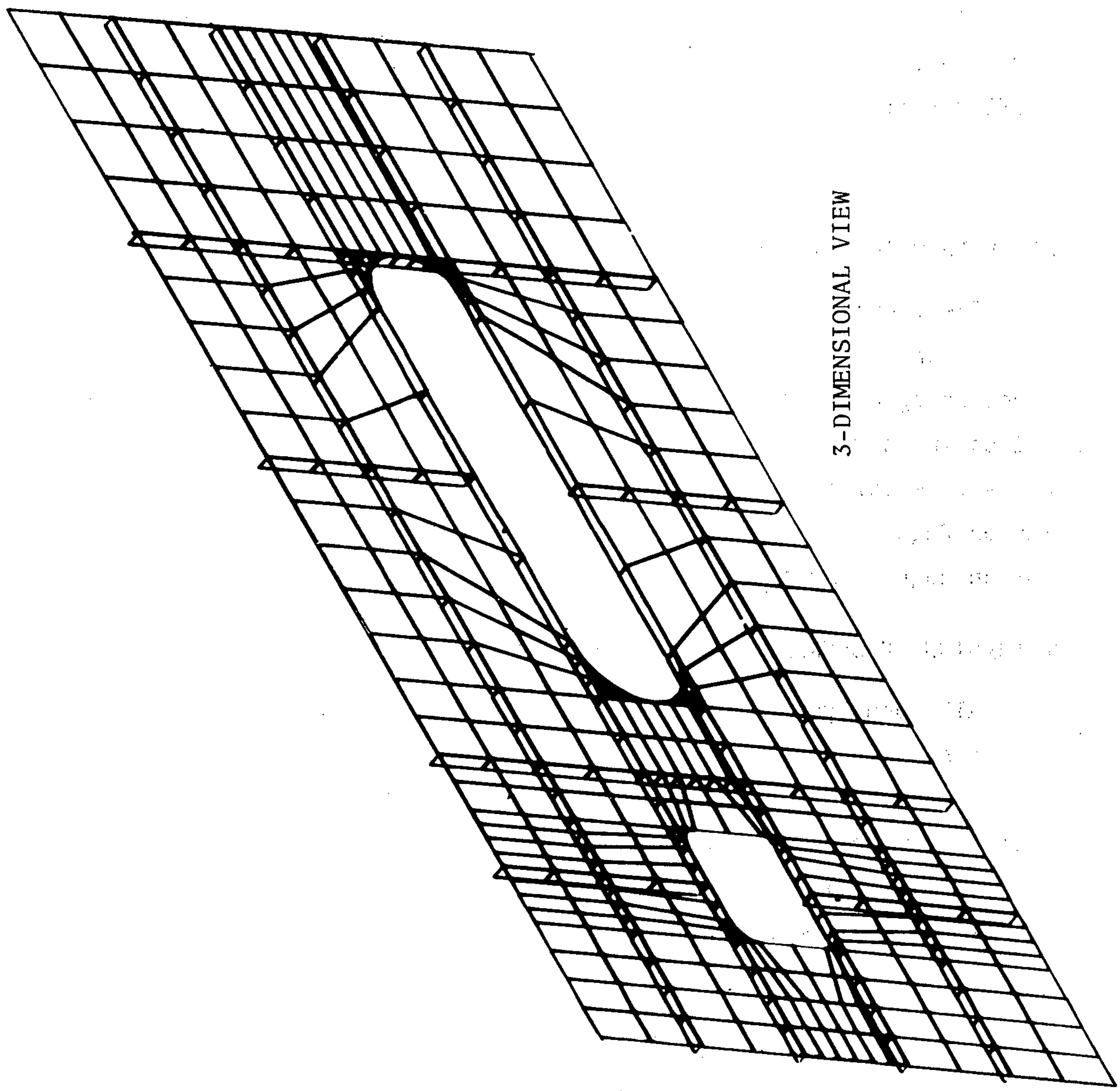
SC-4020 PLOTS

The following plots are produced by the SC-4020. They serve as a guide to the validity of the output generated from DATGEN.



PLANAR VIEW

(This view shows the deck plating represented by quadrilateral and triangular elements)



3-DIMENSIONAL VIEW

SUMMARY OF TEST EXAMPLE

Running time for the program DATGEN as well as the time necessary for NASTRAN to plot the generated output will vary according to the complexity of the problem. The test example contained 712 elements and 613 grid points. With property cards, load cards, and constraint cards included, the total output came to 1777 cards. The total time required to run DATGEN and to run NASTRAN to obtain four SC-4020 plots was approximately 300 CPU seconds.

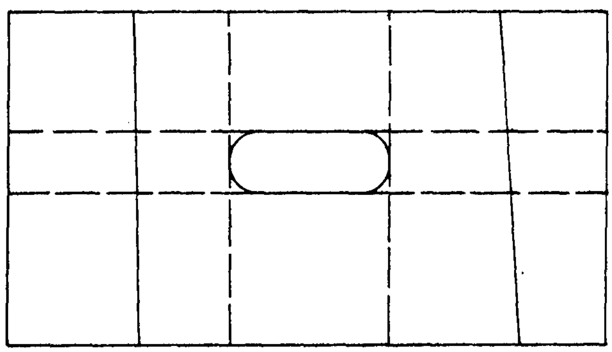
RESTRICTIONS

DECK PLATE COORDINATE SYSTEM

The four edges of the deck assembly must be numbered in a clockwise direction and in consecutive order. Edges 1 and 2 must have their y-values in increasing order between Edges 2 and 4. Edges 2 and 4 must have their x-values in increasing order between Edges 1 and 3. A longitudinal stiffener is considered to have its initial point on Edge 1 and its terminal point on Edge 3. A transverse stiffener is considered to have its initial point on Edge 4 and its terminal point on Edge 2.

THE FRAMING OF OPENINGS

All openings must be framed by two longitudinal and two transverse stiffeners or stiffener generators (i.e., if the openings are not framed by transverse and longitudinal stiffeners, the user can frame the openings by using terminated stiffeners which have zero length). A typical opening framed by four terminated stiffeners is illustrated below. Dashed lines represent terminated stiffeners and solid lines represent continous stiffeners.



STIFFENERS WHICH INTERSECT OPENINGS

A stiffener can intersect an opening only at the straight boundaries of the opening (i.e., no stiffener can intersect an opening along its curved parts).

FUTURE WORK

The current version of DATGEN elementizes a deck structure with a constant z(height) (i.e., a planar structure). With modifications, mainly to the routines which compute the coordinates, the program can be extended to handle a deck with a constant slope or bulkhead. A more complicated but necessary problem is that of elementizing the curved hull of a ship. Since the majority of the hull surface is composed of curved plates, a method of determining the coordinates internal to the grillage (given either the offsets or the functions at the edge of the plate) would have to be derived. With these modifications, DATGEN would be able to handle virtually any portion of a ship structure.

ACKNOWLEDGMENTS

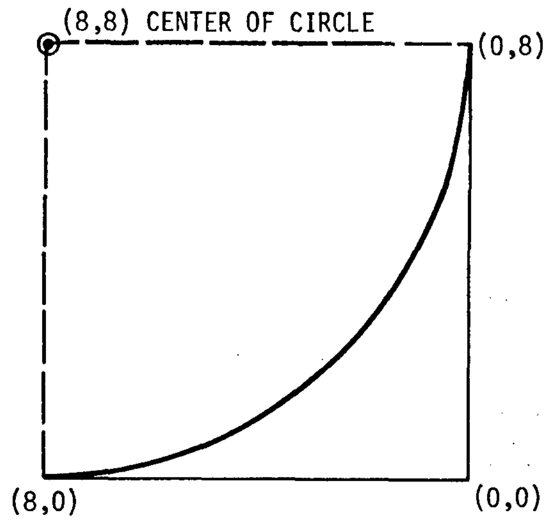
The author is grateful to Messrs. Natale Nappi of Code 853 and Ken Spates of Code 735 for their suggestions and assistance.

APPENDIX A

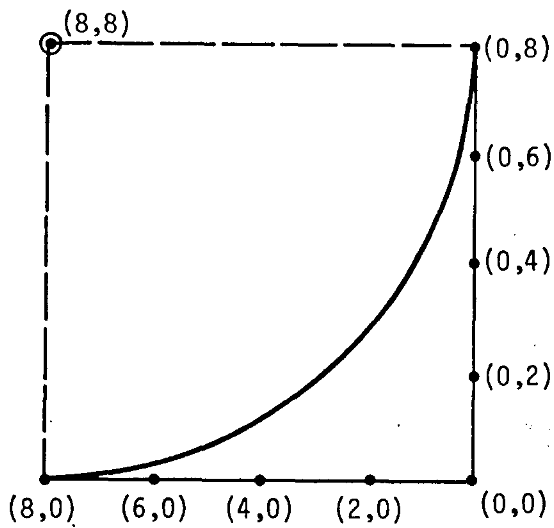
CORNER DIVISIONS

Four quarter circles must be elementized for each corner opening. All four corners are elementized in the same manner and each contains the same number of elements. The fineness of the corner mesh depends on the input variable NDIV(I). The number of elements for the corner of the I^{th} opening = $2x \sum_{g=1}^{NDIV(I)} J$.

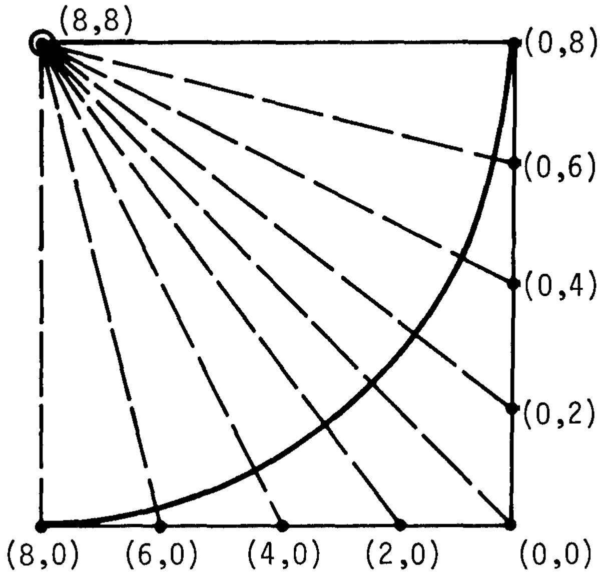
A brief example of a typical corner breakdown will explain how the corner is divided. Assume that NDIV(I) = 4 and that the corner with its coordinates is as pictured below.



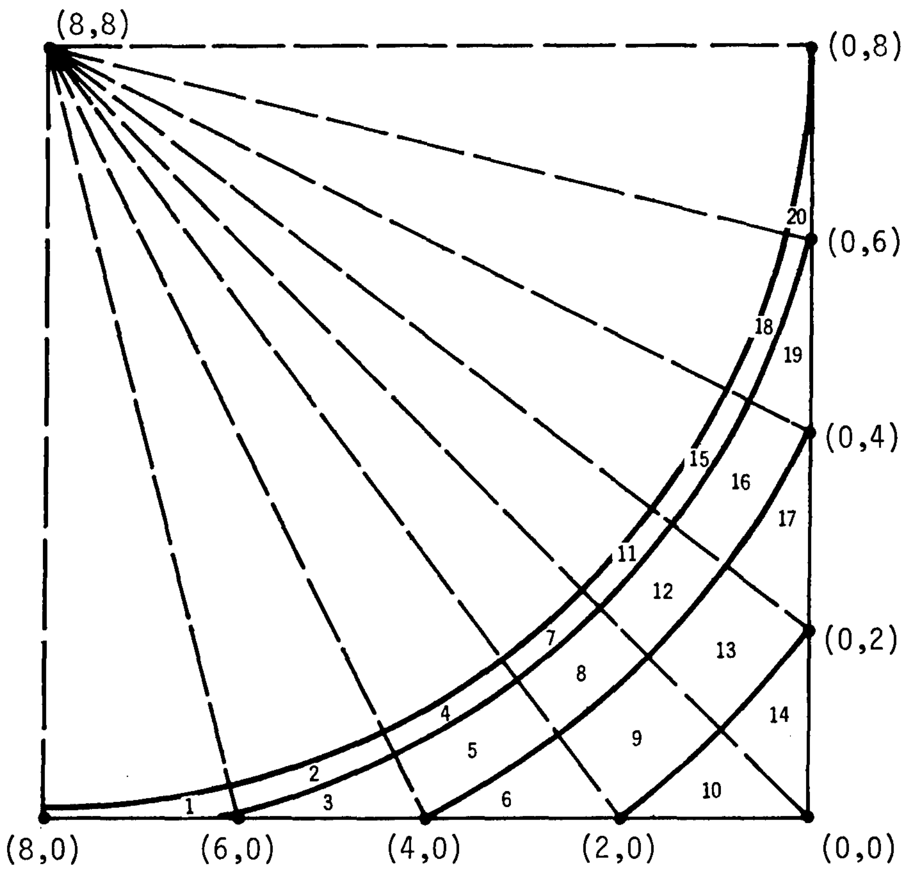
1. Divide each side into four equal parts. (Note: NDIV(I)=4)



2. Connect each point along the sides to the center of the circle.



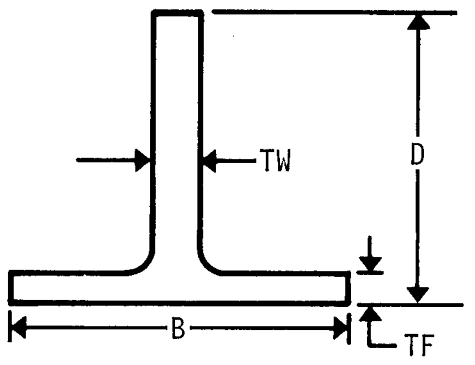
3. Join corresponding points along each side by a circular arc determined by the pair of points and the center of the circle. This is the complete corner breakdown. Note: $2 \times \sum_{j=1}^{4} j = 20$.



APPENDIX B

STRUCTURAL SHAPE CATALOG

This structural shape catalog contains the geometric properties of the standard Navy I-T and T-beams. The beams are arranged in order of increasing sectional area. The symbols used in the listing are illustrated below.



In this illustration B is the flange width of the T-beam. D is depth of the T-beam, TW is the thickness of the web, and TF is the thickness of the flange; all values are in inches.

The following is a sample listing of values given by the computer.

STRUCTURAL SHAPE CATALOG

K-TEE VALUE	WEB DEPTH	WEB THICK.	FLANGE BREADTH	FLANGE THICK.
1	3.000	.110	1.840	.170
2	3.500	.130	2.080	.180
3	4.000	.140	2.280	.190
4	6.000	.110	1.840	.190
5	7.000	.130	2.080	.190
6	2.920	.170	3.940	.190
7	5.000	.160	2.680	.200
8	3.950	.170	3.940	.200
9	8.000	.140	2.280	.190
10	4.940	.180	3.950	.200
11	6.000	.180	3.060	.230
12	5.820	.170	3.940	.190
13	3.000	.230	4.000	.280
14	4.000	.230	4.000	.250
15	5.960	.200	3.970	.220
16	10.000	.160	2.690	.190
17	7.900	.170	3.940	.200
18	5.000	.230	4.000	.270
19	4.060	.250	4.010	.310

K-TEE VALUE	WEB DEPTH	WEB THICK.	FLANGE BREADTH	FLANGE THICK.
20	3.130	.260	4.030	.400
21	6.000	.230	4.000	.270
22	6.000	.230	4.000	.280
23	5.060	.240	4.010	.330
24	4.000	.230	5.250	.310
25	7.000	.210	4.000	.270
26	9.860	.180	3.950	.200
27	12.000	.180	3.060	.250
28	5.130	.250	4.020	.390
29	6.080	.240	4.010	.350
30	8.000	.230	4.000	.250
31	4.070	.250	5.270	.380
32	4.940	.240	5.750	.340
33	6.160	.260	4.030	.420
34	6.240	.260	4.030	.400
35	8.120	.250	4.010	.310
36	11.900	.200	3.970	.220
37	10.000	.230	4.000	.270
38	8.000	.230	5.250	.310
39	5.040	.250	5.760	.430
40	10.120	.240	4.010	.330
41	12.000	.230	4.000	.270
42	5.980	.240	6.500	.400
43	8.140	.250	5.270	.380
44	10.240	.250	4.020	.390
45	5.110	.290	5.800	.500
46	12.160	.240	4.010	.350
47	9.900	.240	5.750	.340
48	6.930	.270	6.730	.380
49	6.040	.270	6.520	.470
50	7.920	.250	6.500	.400
51	12.300	.260	4.030	.420
52	7.000	.290	6.750	.450
53	10.080	.250	5.760	.430
54	6.120	.310	6.560	.560
55	7.930	.300	6.990	.430
56	8.060	.290	6.540	.460
57	11.940	.240	6.500	.400
58	7.060	.310	6.780	.510
59	10.220	.290	5.800	.500
60	8.000	.310	7.000	.500
61	12.080	.270	6.520	.470
62	13.860	.270	6.730	.380
63	9.740	.290	7.960	.430
64	8.060	.350	7.040	.560
65	14.000	.290	6.750	.450
66	12.240	.310	6.560	.540
67	9.000	.360	7.500	.570
68	8.130	.380	7.070	.630
69	9.940	.320	7.990	.530
70	15.840	.300	6.990	.430
71	11.940	.290	8.000	.520
72	14.120	.310	6.780	.510
73	9.060	.390	7.530	.630
74	16.000	.310	7.000	.500
75	7.930	.410	8.460	.650
76	10.120	.350	8.020	.620
77	13.680	.310	8.000	.530
78	9.120	.420	7.560	.700
79	12.060	.340	8.040	.580
80	10.490	.400	8.240	.620
81	8.940	.400	8.710	.690

K-TEE VALUE	WEB DEPTH	WEB THICK.	FLANGE BREADTH	FLANGE THICK.
82	8.000	.440	8.500	.720
83	16.120	.350	7.040	.560
84	13.800	.340	8.030	.590
85	12.180	.370	8.080	.640
86	10.570	.430	8.270	.690
87	12.060	.350	10.000	.580
88	9.000	.440	8.750	.750
89	8.080	.490	8.540	.800
90	16.240	.380	7.070	.630
91	13.940	.370	8.060	.660
92	10.620	.460	8.290	.740
93	18.000	.360	7.500	.570
94	12.180	.360	10.010	.640
95	11.950	.440	8.980	.680
96	9.080	.480	8.790	.830
97	8.160	.530	8.590	.880
98	18.120	.390	7.530	.630
99	13.900	.380	10.000	.640
100	15.860	.410	8.460	.650
101	12.040	.470	9.010	.770
102	18.240	.420	7.560	.700
103	16.000	.440	8.500	.720
104	17.860	.400	8.710	.690
105	14.160	.420	10.040	.720
106	20.980	.400	8.240	.620
107	12.150	.520	9.060	.870
108	13.450	.490	9.990	.750
109	14.180	.450	10.070	.780
110	18.000	.440	8.750	.750
111	16.160	.490	8.540	.800
112	12.000	.470	12.000	.780
113	21.120	.430	8.270	.690
114	14.060	.430	12.000	.720
115	13.530	.520	10.020	.830
116	9.160	.550	11.790	.910
117	21.240	.460	8.290	.740
118	14.910	.550	10.480	.760
119	18.160	.480	8.790	.830
120	16.320	.530	8.590	.880
121	23.900	.440	8.980	.680
122	13.640	.570	10.070	.930
123	15.000	.560	10.500	.850
124	16.160	.500	11.500	.800
125	20.860	.500	8.960	.800
126	12.160	.560	12.090	.930
127	18.320	.530	8.840	.910
128	24.080	.470	9.010	.770
129	16.320	.540	11.530	.880
130	16.550	.580	11.510	.860
131	18.160	.510	11.750	.830
132	24.280	.520	9.060	.870
133	21.140	.580	9.040	.940
134	24.000	.470	12.000	.780
135	26.900	.490	9.990	.750
136	16.660	.600	11.530	.960
137	18.320	.550	11.790	.910
138	17.920	.630	11.970	.940
139	27.060	.520	10.020	.830

K-TEE VALUE	WEB DEPTH	WEB THICK.	FLANGE BREADTH	FLANGE THICK.
140	21.000	.530	13.000	.870
141	18.480	.600	11.830	.990
142	24.160	.510	12.040	.860
143	29.820	.550	10.480	.760
144	24.300	.560	12.090	.930
145	27.280	.570	10.070	.930
146	30.000	.560	10.500	.850
147	24.240	.570	14.000	.900
148	30.160	.590	10.520	.930
149	33.100	.580	11.510	.860
150	30.300	.620	10.550	1.000
151	24.480	.610	14.040	1.020
152	26.880	.600	13.960	.980
153	33.300	.610	11.530	.960
154	24.720	.660	14.090	1.140
155	27.080	.660	14.020	1.080
156	33.500	.640	11.560	1.060
157	35.840	.630	11.970	.940
158	29.880	.660	14.980	1.070
159	36.000	.650	12.000	1.020
160	27.300	.730	14.090	1.190
161	36.160	.680	12.030	1.100
162	30.120	.710	15.040	1.190
163	36.320	.730	12.070	1.180
164	33.000	.720	15.750	1.150
165	36.480	.770	12.120	1.260
166	30.380	.780	15.100	1.320
167	33.240	.780	15.810	1.280
168	35.880	.770	16.470	1.260
169	33.500	.830	15.860	1.400
170	36.060	.800	16.510	1.350
171	36.240	.850	16.550	1.440
172	36.500	.860	16.590	1.570
173	36.720	.940	16.650	1.680

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13. ABSTRACT

A computer program has been developed for the automatic elementizing of flat-plated ship structural grillages with up to five openings and uniform pressure loads normal to the planar surface. Its purpose is to shorten the preliminary work of preparing data for analysis by the finite element method. The input to the program consists of punched cards which define the plate geometry, and the output consists of a tape which is directly read by the general-purpose finite element program NASTRAN to produce a plot of the user's elementized structure.

Modifications to this program will shortly be undertaken to allow the program to accept in-plane loads and hull geometry.

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14 KEY WORDS	LINK A		LINK B		LINK C	
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Data Generator, Deck Assembly, Finite Element, Mesh Generator						

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